Port Harbour Structures
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Module 9, Lecture 46
Design and construction of diaphragm wall

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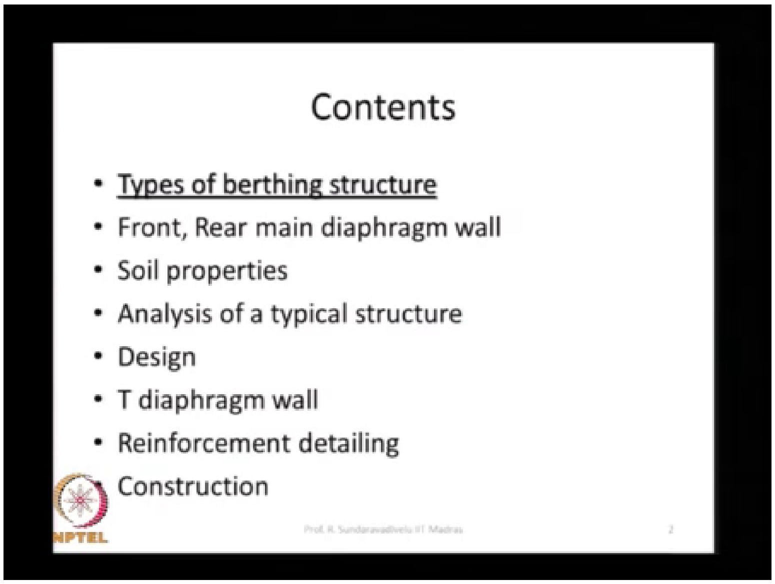

So in this class we will see the design and construction of diaphragm wall, there are different types of berthing structures which I will explain then we will talk about this diaphragm wall,

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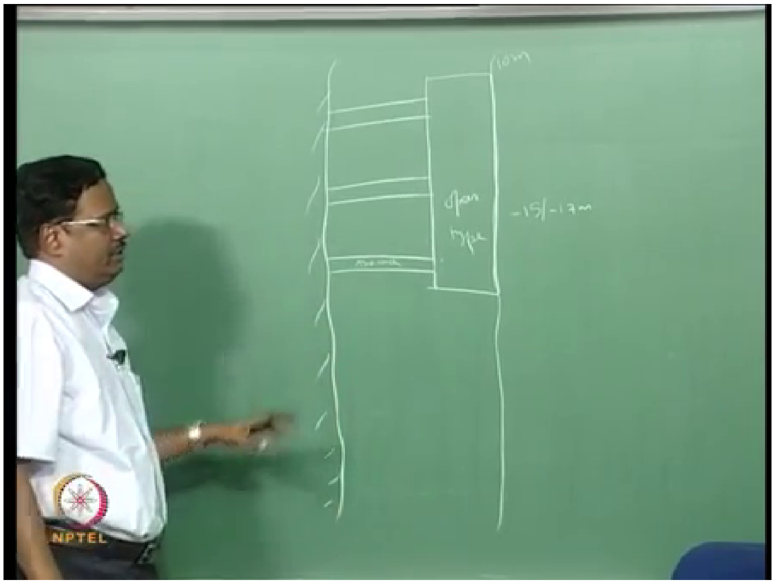

Assume this is the shoreline and the assume that this is your 10 meter contour another procedure to construct the structure is you construct the structure somewhere here and provide some approaches this called as open type structure, here there is no diaphragm wall.

Shoreline is the line at which you will have the water level zero and bed level will be more than zero or you can fill up this area this is the open type structure, here you will have 10 meter water depth and you can dredge this area to minus 15 meter afterwards or minus 15 or minus 17 meters there is no diaphragm wall it is a open pile structure there will be an approach then you can construct the structure, this is structure in which there is no diaphragm wall.

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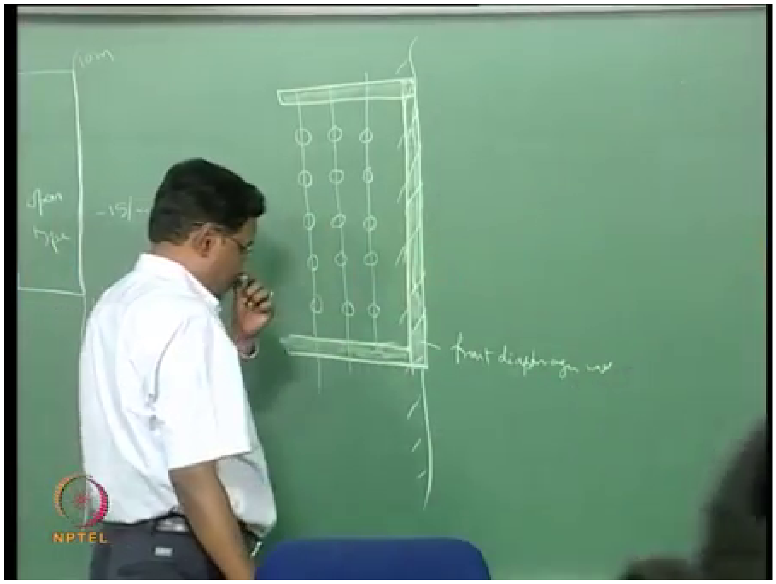

There is no continuous which is retaining the soil the other type of structure is this is your shoreline what you do is you build one structure here what is called as a diaphragm wall this is known as the front diaphragm wall, basically you have to extend this on the ends when you have certain rules of piles.

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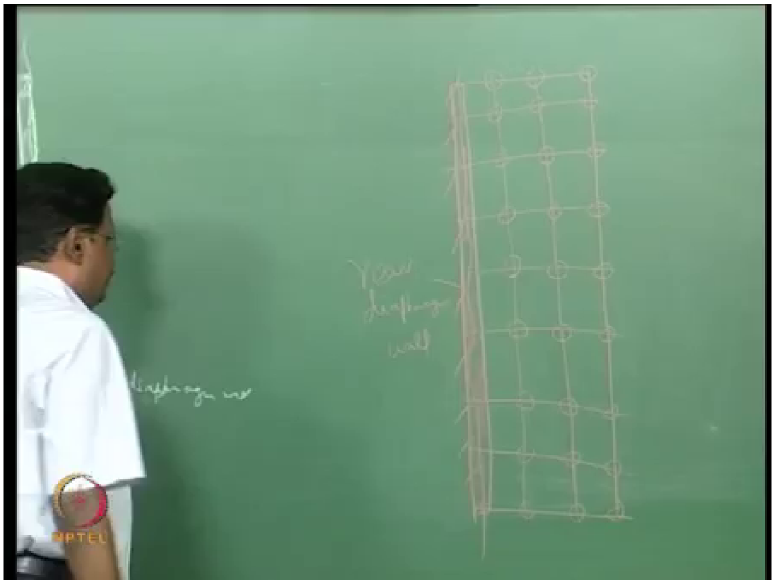

There is another type of structure in which suppose you have the shoreline here you construct the diaphragm wall here but the piles on the front.

So this is called as a rear diaphragm wall, so we have a open type structure with approaches from the shoreline to the jetty then there is a front diaphragm wall with piles on the backside so this front diaphragm wall the top level here will be plus five the dredge level will be here minus 17, let us say we are designing it for minus 17 whereas in this type of structure this level will be minus 17 and this level will be plus 5 but this bed level here since we are coming here.

Let us say about 30 meter or so and assuming one in three slope the bed level will be minus 7 that means the difference in soil (pre) the difference in bed level is this side plus 5 this side minus 7 that is 12 meter is the difference whereas here it is plus 5 here and minus 17 here it is 22 meters, this time there is no earth pressure is it clear, so what here we are doing is if you see this figure suppose this is the structure what is shown here structure is shown here.

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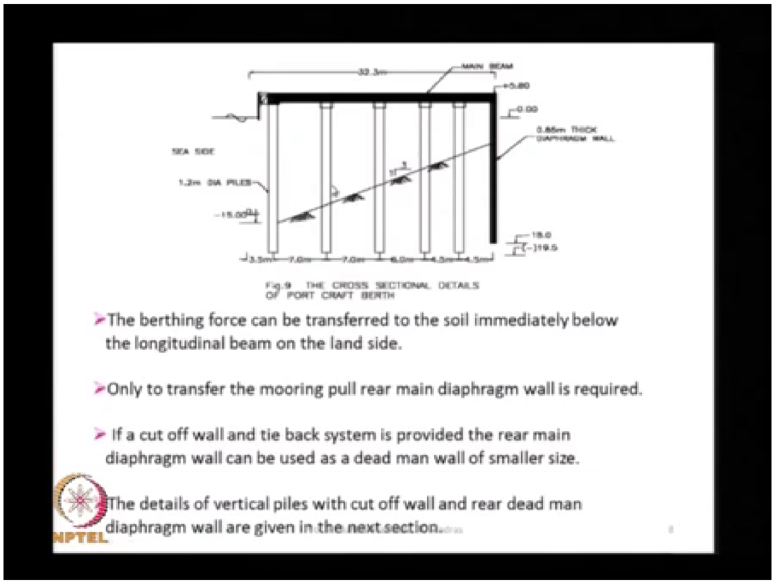

Here we have more number of piles we have about 1, 2, 3, 4, 5 piles here the bed level is minus 15 you have the piles here, piles means it is a discontinuous structure it is not retaining the soil and when it comes to this place here we have a rear diaphragm wall here we have slope of one is to three suppose this distance is about 32 meters this 1 is to 3 means the bed level will be 10 meter less here it is about minus 5.

Top level is 5.8 that means it is retaining the soil only for 10.8 meters any doubt in this, now understood what is the diaphragm wall, diaphragm wall is nothing but a retaining structure which retains the soil and it doesn't allow the soil to collapse, it’s a continuous structure is it clear or not, what is it see depth means it has to go below the sea below this bed level to sufficient depth that we will be calculating, I will tell how to calculate that, a pile depth criteria is different.

Diaphragm wall criteria is different, I will tell you how to define the pile depth how to define the diaphragm wall both the things will be explained, this class I will explain what is a diaphragm wall depth,

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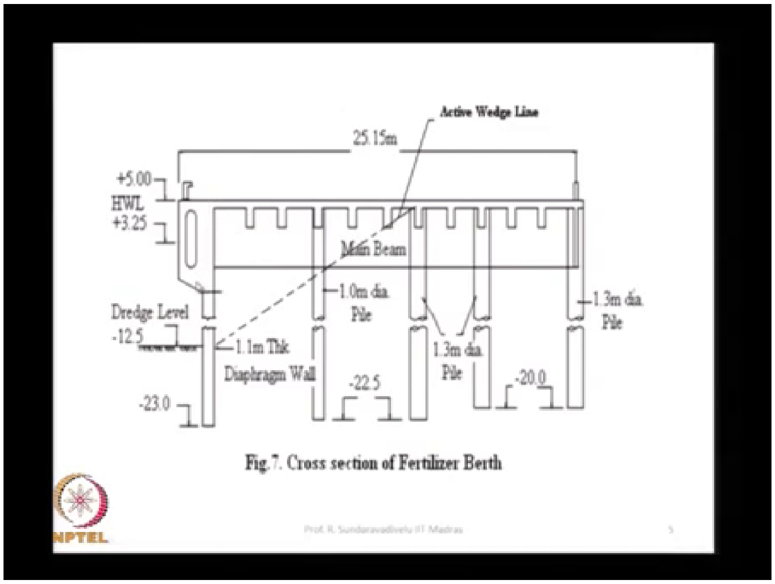

The other case what is shown here is it is a front diaphragm wall. Here the dredge level is minus 12.5 top level is plus 5 but it has to take the earth pressure from plus 5 to minus 12.5 that is about 17.5 meter it has to take and the piles are on the backside.

These are the all the piles which are on backside this is the diaphragm wall that is this type of structure

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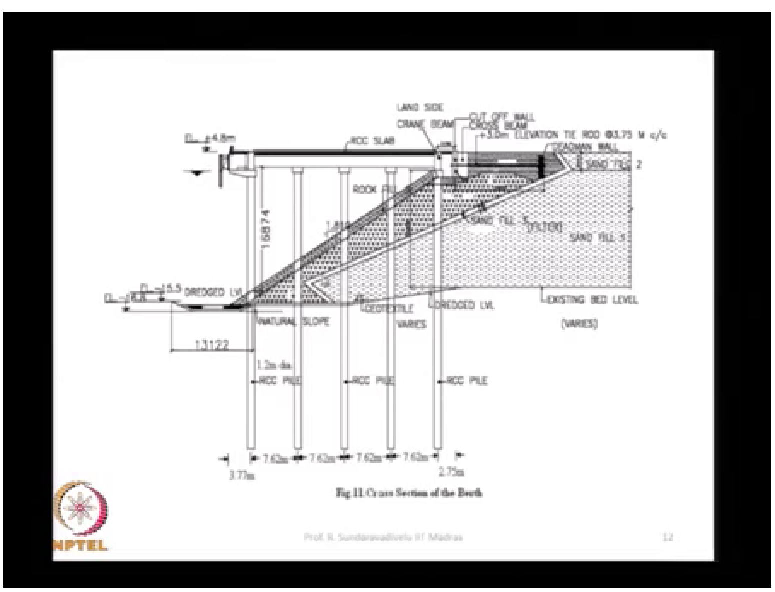

There is one more structure which is in between these two which is recently done this is a type of structure, this is something like this in this type of structure what we are doing is

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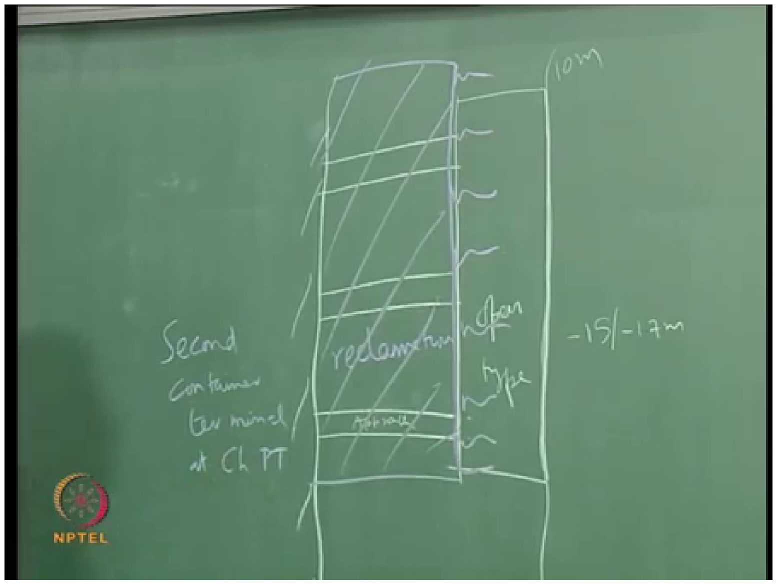

We are filling this area with a slope so that this will be used for this is a reclined area reclamation is carried out so this is used in second container terminal. At Chennai port trust so here you can stack the containers so here what you are seeing is this is a slope what I have shown by this line

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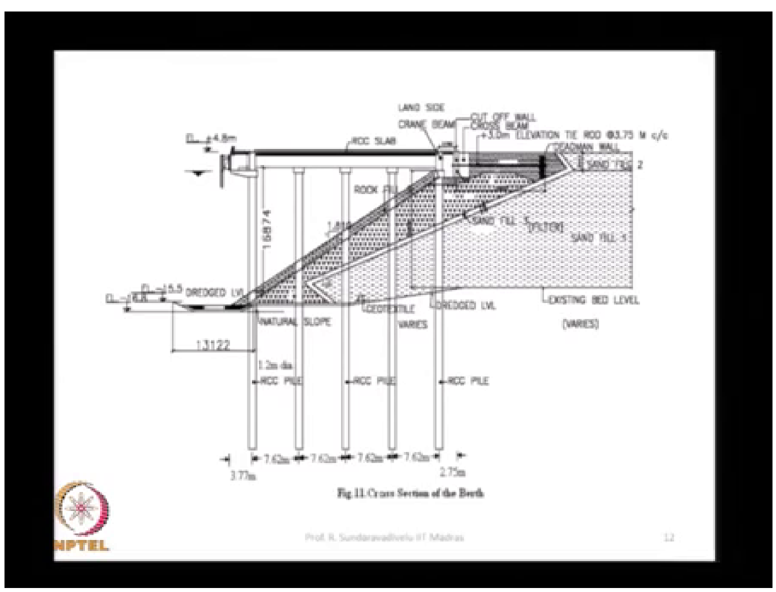

This line is that slope this is a structure and we put some tie back system for mooring pull and we fill this entire area by sand then we put some rock to embankment this is called as a rock fill what we are giving here in this slope is rock fill,

What is shown in the board is the plan that is when you look from the top. How it will be seeing what I am showing in the power point is the cross section how it will be like that, so this is done in Paradeep port, this is done in Jnpt out of these three concept which will be better, what is done in Chennai port or what is done in Paradeep port or what is done in Jnpt which will be better?

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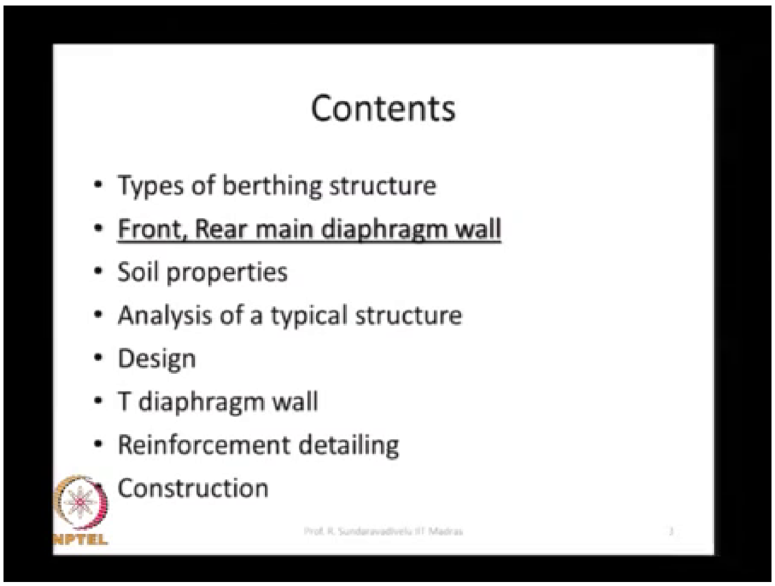

That is what is done in Paradeep port see Paradeep port the problem is see whenever we go for the design there are three parts in a design.

One is estimation of force, second is analysis, third is the design these are the three components for any design first is the force estimation, second is analysis, third one is the design if we talk about the forces for which structure the force will be less first structure or second structure or third structure, first will be less because there is no earth pressure, earth pressure is taken by to rock to embankment which will be more? First one, second one, or third one?

Not third second only, second the top level is plus 5 dredge level is minus 17 that means 22 meters it has to retain the soil that means the force will be more, see if you assume all the cases the bed level is minus 17 top level is plus 5 the first case there is no earth pressure it has to retain there is no differential water pressure it has to retain, second case it has to retain from plus 5 to the dredge level minus 17 that is 22 meters, the third case it is from plus 5 to minus 7.

That is only 12 meters right based on that is why the front diaphragm wall or rear diaphragm wall these are the two cases there are certain cases where we go for no piles at all this is another case.

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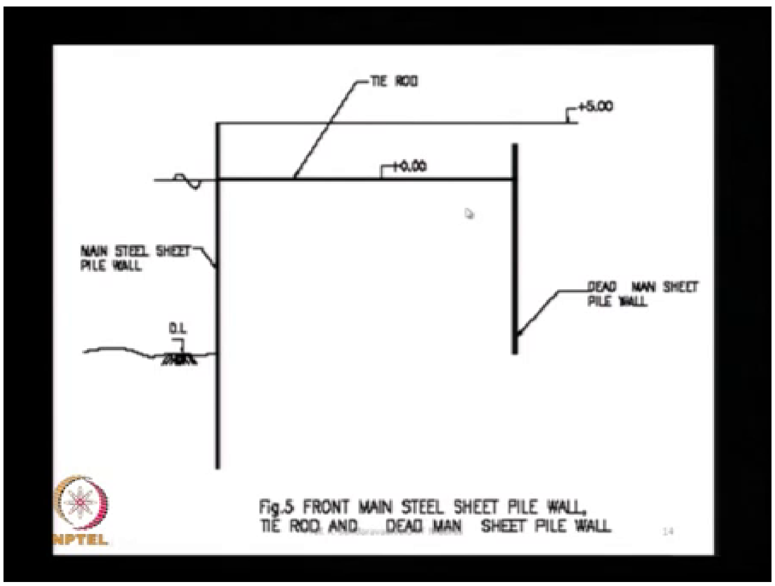

This is the main diaphragm wall in the front this is the rear diaphragm wall, then you connect it by a tie back system the whole area is filled up and the soil is suppose to take all the load, this is another type is system that is practiced so we have a front diaphragm wall.

We have a rear diaphragm wall which is a dead man wall so we will be discussing about the main diaphragm wall, main diaphragm wall means it is retaining the soil, so this is the terminology which we will be discussing so whether we have a front diaphragm wall, main diaphragm wall or rear main diaphragm wall or no diaphragm wall these are the three cases which we will be discussing and the forth case what we will be discussing is.

We will have a front main diaphragm wall and the rear dead man diaphragm wall, dead man diaphragm wall is the structure which doesn't allow the main diaphragm wall to fall back that is why it is created, it is an anchor wall.

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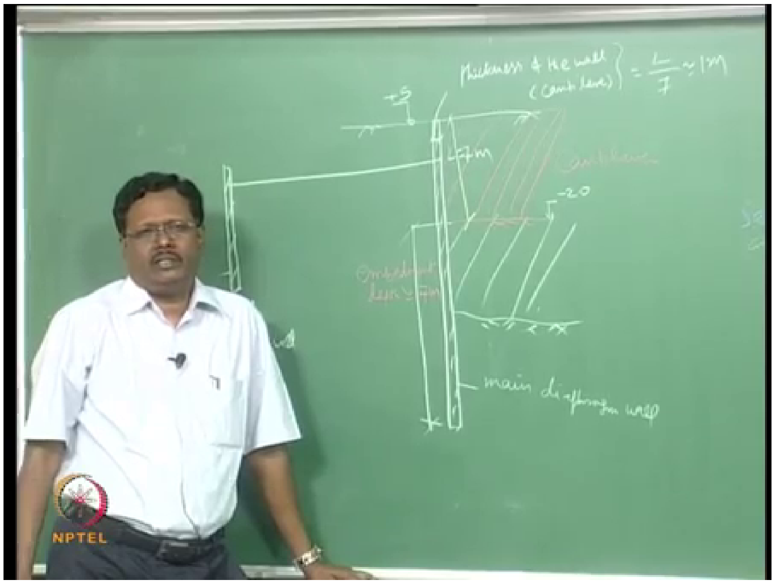

So the construction is either concrete or steel, suppose let us say it is a concrete structure is continuously built while building we will have a soil level at both the sides same then what we will be doing is we will be removing the soil to certain level.

Suppose you remove this much portion of soil that is this much portion of soil is removed what happen this diaphragm wall acts like a cantilever diaphragm wall right, this is called as a cantilever diaphragm wall that means we will do dredging and remove the soil on the sea side so that the ships will come and rest this is for fishing Harbour it is done so this is called as a cantilever diaphragm wall there is no tie back, suppose you want to dredge deeper.

Suppose you are going right up to this more depth is there that means you are removing this much soil also, so what happen this embedment depth is not sufficient so it will not take the load then what you do is you put a tie rod then put a dead man wall, suppose generally this level is about plus 3 or plus 4 or plus 5, I will assume it as plus 5 generally used as minus 2 for fishing Harbours or up to about 7 meter of unsupported length.

You can use this cantilever type diaphragm wall, cantilever type means there is only the diaphragm wall with sufficient embedment depth, this embedment depth is approximately equal to 7 meter for medium type soil if it is a very good soil you can take 75 percent of this but you have to do the calculation I will tell how to do the calculation let if we go more than 7 meter see for 7 meter embedment depth this thickness of the wall that is a thickness of the wall.

This is for cantilever type is this length is 7 L by 7 that is approximately 1 meter if you see this span by deflection ratio in is456 for a cantilever they say the depth of the cantilever should be span by 7 so if there is a beam here there must be a beam here but they have (not) they have put the fall ceiling

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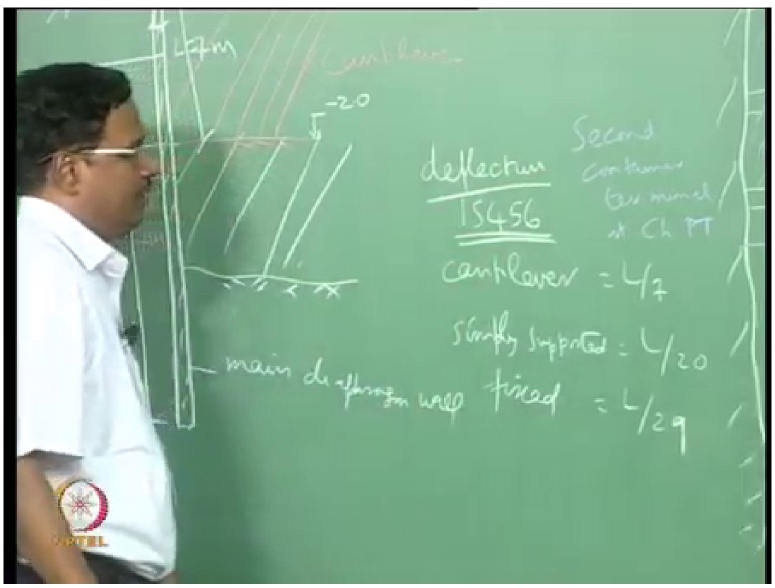

There are three cases given one is cantilever, another is simply supported (third) the next is fixed cantilever is L by 7 fixed is L by 20.

I think this is L by 27 or so right, by 29 I don't remember it is given in is456 see serviceability criteria we have to check for deflection but if you provide the depth greater than L by 7 if it is a cantilever you don't check for deflection, if we provide more than L by 20 you don't have to check for simply supported more than L by 27 or 29 you don't have to check for fixer is what is given here.

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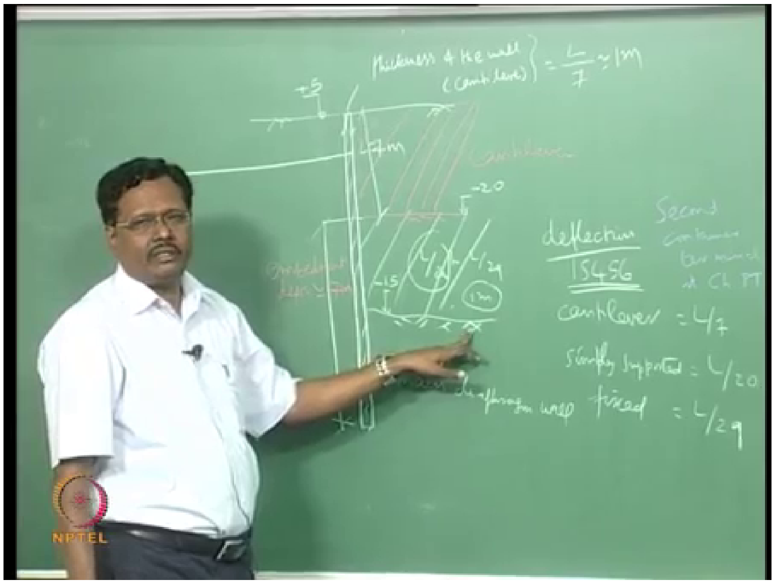

But when you go for this case this will be in between this L by 22, L by 29. Suppose we take L by 20 and this distance we take it as minus 15 so this is 5 meter this is 15 meter so this is 20 by 20 this also is 1 meter so the same 1 meter thickness we can provide for the diaphragm wall even if the dredge level is minus 15 (provided you pro) substitute an anchor right is it clear.

If you don’t do it for cantilever this minus 15 plus 5 20 meter 20 by 7 is how much 20 by 7 close to 3 meter you want to provide this as a cantilever. You have to provide 3 meter thickness very difficult to do that is why you go for a tie back system right

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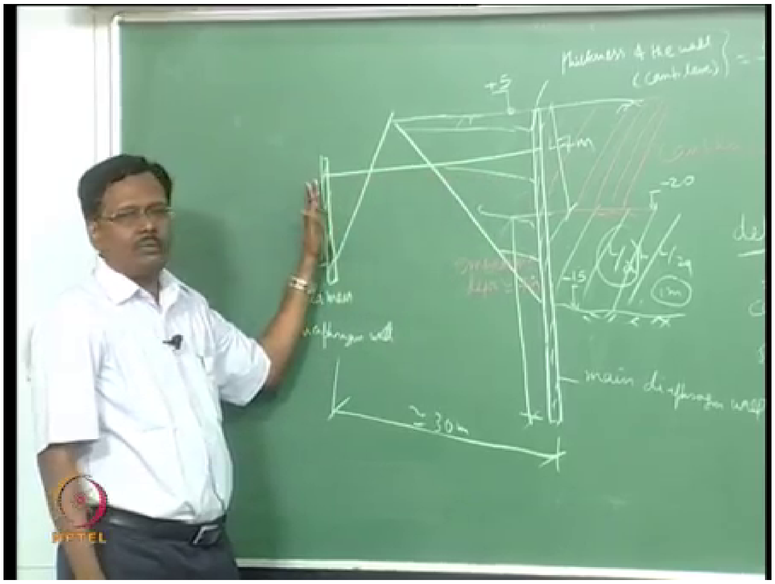

And when you provide a tie back system this soil is collapsing the soil will go down like this, suppose this diaphragm wall is not there assumed that the diaphragm wall is not there and your dredging up to minus 15 what will happen to the soil, soil will not remain vertical it will collapse, this is angle of repost it will collapse so up to this area even if you provide a pile.

Here it will not provide any resistance, similarly here also there is a distance called passive resistance so this distance should be sufficiently more it's about typically about 30 meters you have to calculate where to locate the dead man diaphragm wall it cannot be very close here if you put the dead man diaphragm wall here what happen it will be in the active zone it will fail anchor wall should be provided far away from the main wall.

I am explaining this here because one of the structure very recently built they have not put the diaphragm wall, dead man wall properly the whole structure has collapsed 45 crores lost, one of the structure very recently some three years back, the other important parameters to be studied are soil properties so I said we have to do force estimation analysis then design the force estimation you should know what is a soil properties.

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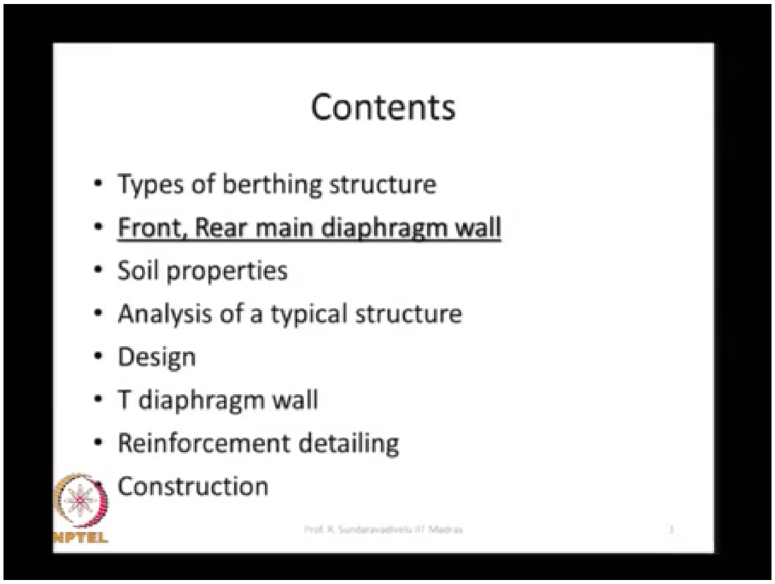

Unless you know the soil properties properly you cannot estimate the force correctly then we have to go for analysis we are doing the analysis using one software called Staad pro then design there are two types of design limit state of collapse and limit state of serviceability then diaphragm wall it can be a rectangular wall or a T wall that also we will see then after this force estimation analysis and design the most important requirement is reinforcement detailing.

The detailing of reinforcement is very important 99 percent of the structures which are failing which have failed is mainly because of improper reinforcement detailing even if you have done the correct estimation of force analysis and design if you don't properly detail the reinforcement and execute in the construction then the collapse will take place so this is important that is the reinforcement detailing as well as construction is important.

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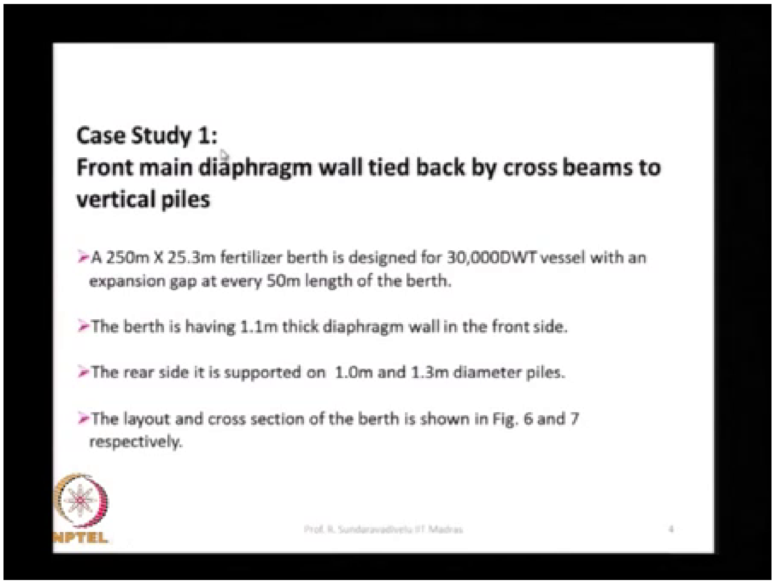

So we will talk about the four case studies the first study is the front main diaphragm wall, tied back by pass beams to vertical piles.

This is for a smaller size vessel the length of the berth is 250 meter, width of the berth is 35.3 meters this is 250 meter is divided into 5 blocks each of 50 meter with a expansion gap, the berth is having a 1.1 meter thick diaphragm wall in the front side.

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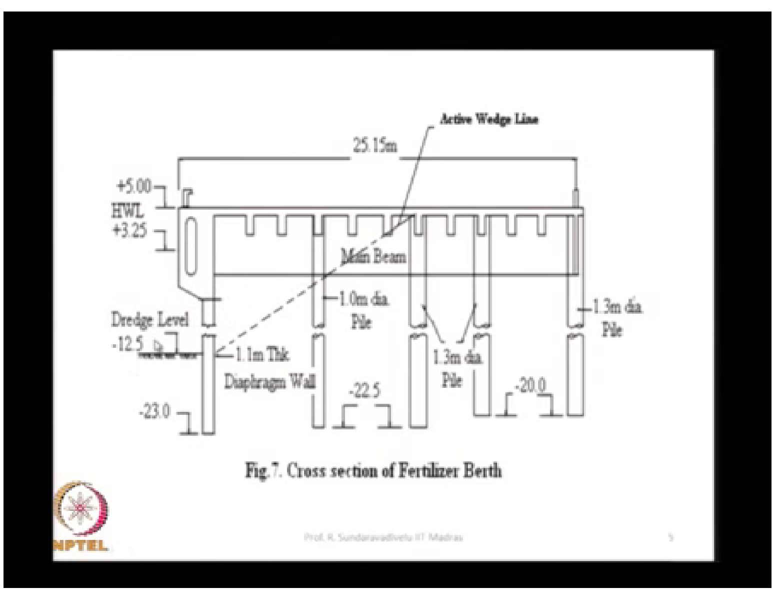

The rear side supported by 1 meter dia pile and 1.3 meter diameter pile and the cross section is shown here this is your front diaphragm wall. Which is 1.1 meter thick, this pile is 1 meter (thick) diameter these two piles are 1.3 meter the last pile is 1.3 meters this angle of repost the soil here will not give any resistance to these piles that is why we are gone for a smaller diameter pile because we don’t expect this to take more because in the active zone of the front diaphragm wall, the embedment depth is given about 7.5 meters.

Below the bed level that is about 23 meters and these two front rows of piles are given 22.5 meter founding level the last two rows are given minus 20 meter founding level this diaphragm wall is continuous but it is made of about 4 meter panels and these piles are spaced at 4 meter center to center then we have a main beam connecting all the structure so when the diaphragm wall is trying to deploy it they transfer the load they are tied back to these piles.

And these piles and these piles will not allow the diaphragm wall to fall down that means whatever force that is acting on the diaphragm wall some portion of it will go below the sea bed some portion will go to the piles back, normally 50 percent of the total force acting on the diaphragm wall will go to the diaphragm wall below the sea bed and the other 50 percent will go to the piles behind, this 50 percent of the force acting on the diaphragm wall.

Will not go equally to all the piles the piles of bigger diameter will take more force the piles in the active zone will take less force.

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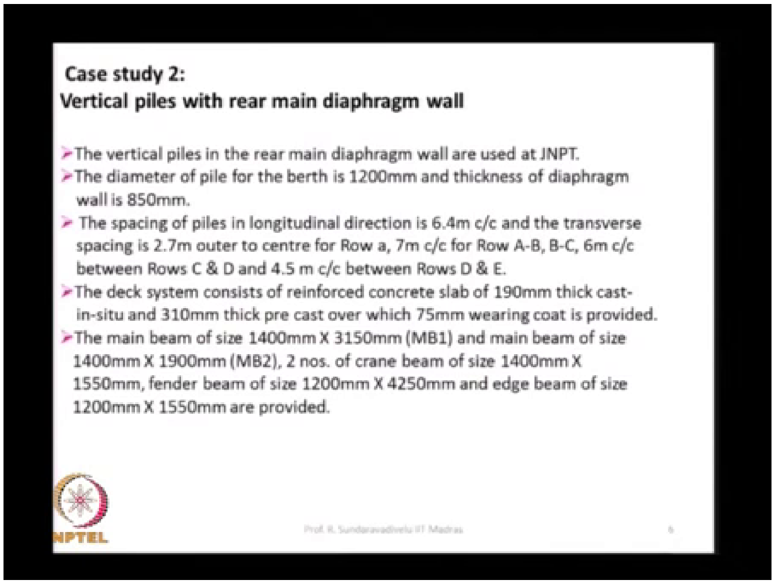

Then we have the next system that is done in Jnpt this is for a diaphragm wall rear main diaphragm wall is,

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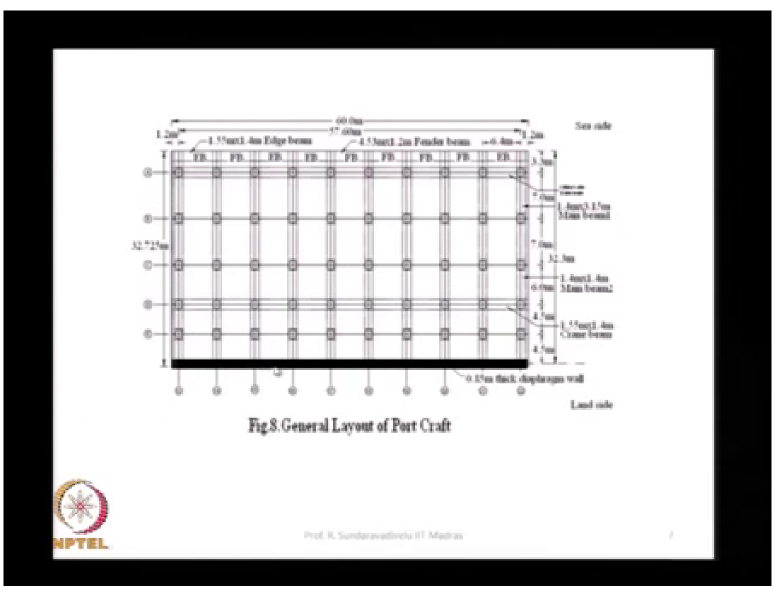

Shown here this is the rear main diaphragm wall this thickness is small 0.85 meter only. We have one, two, three, four, five rows of piles typically five rows of piles are used, this is the sea side this is the land side. And the total length of this diaphragm wall is given here

I don't think it is given here it is for a typical block of 60 meter like that we have multiple blocks having it total it is for about 600 meter or so total length and there is a spacing in this direction we have given this in a row numbers one, two, three, four, five, six like that this is numbers are given here this side is given a, b, c, d, e and this is your f row and these piles are of different diameters.

Diameters are given here 1200mm thick minimum 1200mm diameter pile and the diaphragm wall thickness is 850 mm spacing of the pile in the longitudinal direction is 6.4 that is this is the longitudinal direction here the spacing is about 6.4 meter center to center and the transverse direction first row is 2.7 meter then 7 meter then 6 meter then 4.5 meter you can see here distance from here to here is I think it is 3.3 it is not 2.7 it is given as 3.3 meter.

From here to here is 7, from here to here is 7 then 6 then 4.5 then 4.5 what is the criteria for fixing this spacing the spacing between the piles how close it can be? We are putting two piles how close you can put two piles suppose the diameter of pile is 1.2 meter the code specifies that the minimum spacing between the pile is about three times the diameter of the pile 1.2 meter means if not put closer than 3.6 meter if it get then you have to do the group affect.

Then the piles will not have the same capacity if it is at a closer spacing the spacing is generally given about 7 meter because for construction purpose when you have to put the pre cast units the weight there is a limitation, maximum spacing is between 7 and 9 meters only the weight is more lifting capacity is more (you have to) here water is there in this area so you have to lift this beams and place it that's why they put about 7 meter spacing.

And from the (25:52 phase your beam) to this central line we provide 3.3 meters mainly because you have to put some bollards there will be some cranes which will be going, you have to put some service trains for all these reasons this gap should be about 3.3 meters, so you can clear with the layout changing the spacing I have given 6.4 you can make it 7, 7.5, 8,9 and see what is the diameter required so if the spacing is more diameter will be increased.

And we have shown two beams here this is for the front crane beam this is for the rear crane beam over which the crane will move this is the rear diaphragm wall the deck system of Rcc slab 190 millimeter thick cast in-situ and 310 millimeter thick pre cast that is the total thickness of the slab is 500 millimeters normally in residential buildings you will see only 200 or 250 mm thickness whereas for Harbour structure we put 500 mm thick.

Because the load on the structure is 50 kilo Newton per meter square whereas for building it is only 5 kilo Newton per meter square and top of it we will have some mobile Harbour cranes which will give a load of 2000 kilo Newton per meter square, very heavy loads patch loads then we have the beam sizes 1400 millimeter by 3150 millimeter and different sizes are given fender beam sizes are given, edge beam sizes given so these are all the requirements for a design.

What is the slab thickness here, what is the beam size here, what is the beam size here all this is govern the design.

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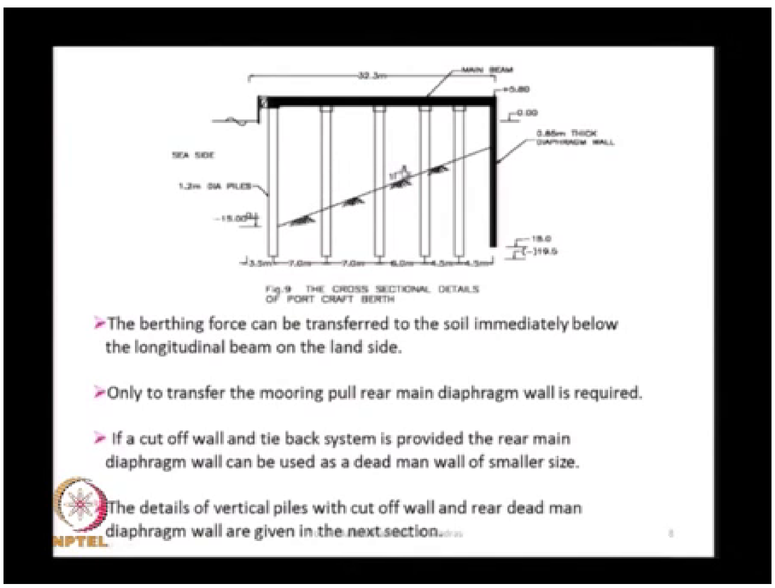

This show the cross section, front pile, the rear piles and the main diaphragm wall which is put on the rear side and plus 5.8 is the level here this is a chart datum, embedment depths are given since the rear diaphragm wall, a main diaphragm wall is provided in the rear side the founding level can be lesser it is minus 18 only.

Whereas here it is minus 19.5 for the piles, it depends on the soil profile here we have rocks available that is why though the dredge level is minus 15 we are stopping at minus (9.) 19.5 so if you provide a rear diaphragm wall the founding level can be lesser compare to the piles, whereas if you see the other case the front diaphragm wall is minus 23 whereas a rear piles are minus 20 this has to be done by design only after doing the analysis we have to do two design.

One is structural design and another is foundation design based on which we have to do so whenever there is a berthing force which is a main force for which this design it is hitting the structure here all the load will go behind the rear diaphragm wall the soil this point is clear no when you are hitting the structure with berthing force the whole load will go behind the soil, soil will take the load only when the vessel is pulling the bollard.

That time the diaphragm wall has to take the load but seismic force in this direction the soil will take but seismic force in this direction the diaphragm wall has to take.

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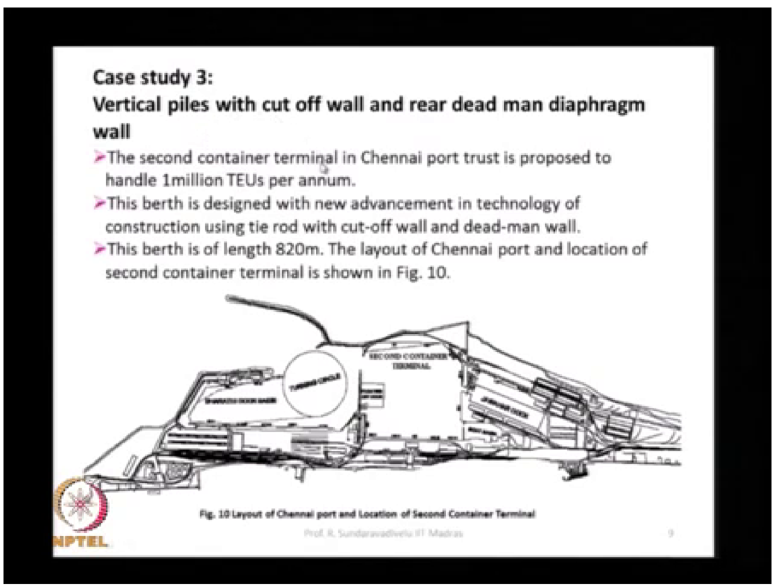

This is the third case study in which these three numbers are different from what is shown in the board this is the different case studies so here what we are doing is we have 820 meter long berth they are dividing into thirteen models they are providing a span joint of 40mm thick.

And every 60 meter the width of the berth is 37 meter we use different types of piles, here we use bored cast-insitu piles the pile spacing is 7.5 meter in the longitudinal direction and the 7.62 meter in the transverse direction we have two crane beams what for we are providing a span joints? What is the reason for providing for providing span joints what happens if there is a thermal expansion and if you don't provide expansion joint, cracks will come.

But you can design it suppose you design it properly you can increase the spacing in Tuticorin we have provide 300 meter without expansion joint but you have to design for it design means when you do the analysis you will design it for temperature difference find out what is the forces in the slab, beam and piles there you can design for it, but normal building the expand joints are provided between 45 meter and 60 meter residential building.

Whereas for berthing structures Tuticorin we have build the 300 meters, Jnpt we have put 150 meters, no expansion joint in between the 150 meters,

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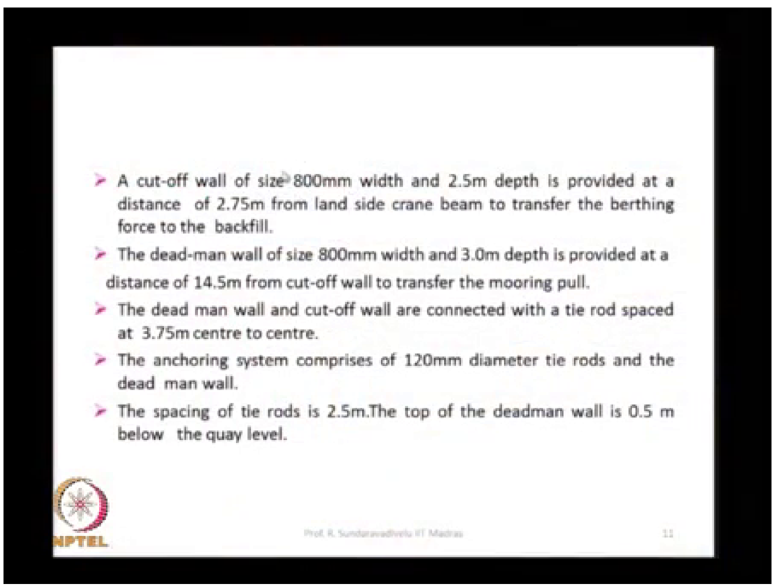

So we are providing one cut off wall then we are providing one dead man wall and then we are connecting these two by tie rod the anchor (di) anchoring system consists of 120 millimeter diameter tie rod and the spacing is 2.5 meter.

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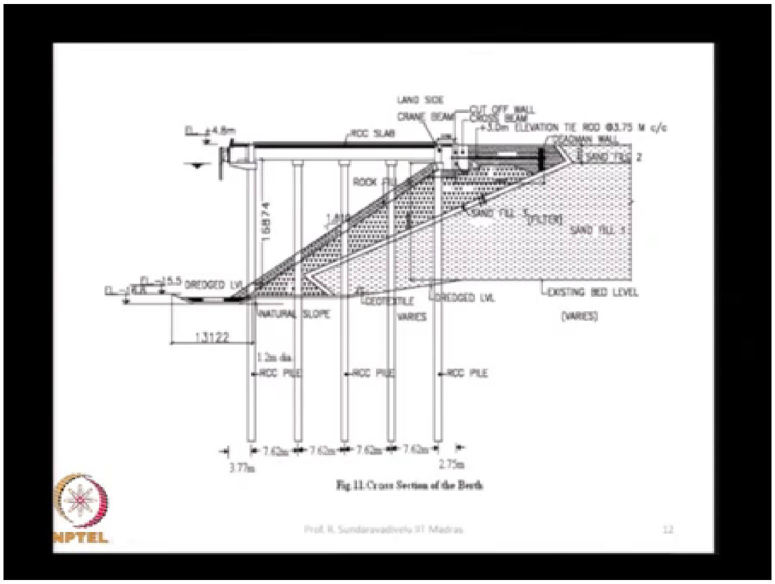

What we are seeing is this is the cut off wall what we are providing here. And this is the dead man wall. This is connected by a tie rod and generally the tie rods are not at the top level it is somewhere at the lower level typically it is at zero zero level or slightly above this dead man see whenever there is a bollard pull so we don't want to transfer it directly to this diaphragm wall here because there is no diaphragm wall so what we do is we want to transfer it to a dead man wall which is kept far away may be it is more than about 15 meter or so.

So the dead man wall will take the tie force that means we have only the piles which are provided the transverse spacing is given 7.62 meter center to center the longitudinal spacing in the other direction is 7.5 whereas the tie rod are provided at every 2.5 meter center to center, the elevation here is plus 3 meter tie rod the top level is plus 4.8 typically this plus 3 meter is the center line of dead man wall, dead man wall will be from plus 4.8 to about minus 1 meter.

So we go to the center and provide this anchor wall this figure is clear to you we build the structure in open sea where minimum dredging is required then (from the) form this portion to this breakwater where it exist in Chennai port we used sand fill then we use some big size stones, this is a core stone then we use armor stone the slope is one vertical to 1.8 horizontal then we anchor this below the bed level by some material which is as big as the armor stones.

This is the fender which will go down below the Os water level (he) this is what is called as a tope protection what is given here so the tope protection given and it is also given to reduce the propeller wash, when the ship is coming propeller is moving the propeller will create some disturbance due to this soil wills cover so this will act like a tope protection plus it will also act like a skiver protection against propeller moment.

Current generated by the propeller, no here dead man wall is may be around 1000 millimeter thick you are asking here or at other places this layout about 1000 millimeter I think or 850 I don't know it is 800 millimeter thick and it is 3 meter depth (and is provide) distance is 14.5 meter that is this is 3 meter width 3 meter depth, this thickness is 800 millimeter the distance from here to here is 14.5 meters that means the active pressure on the cut off wall.

And the passive pressure on the dead man wall should not meet there should be a gap, this structure is found to be about 30 percent economical compare to any other structure which have built earlier.

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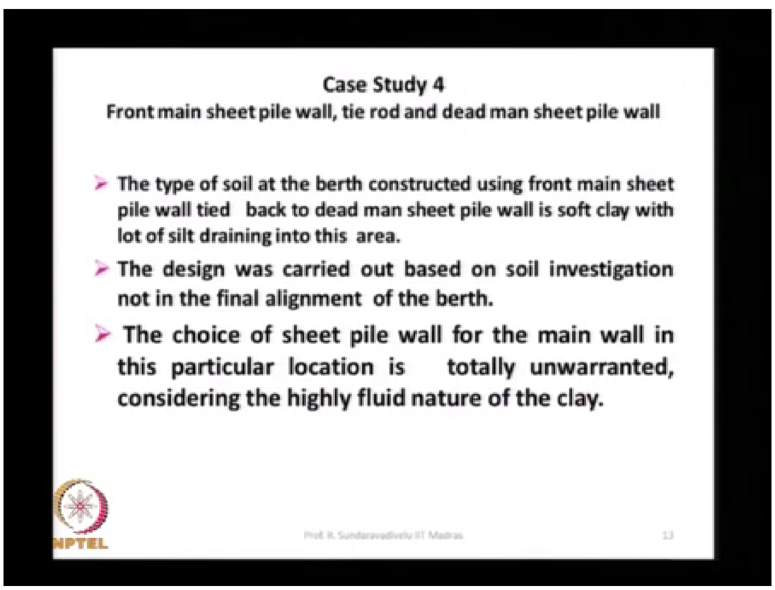

Now we will complete this lecture class with this case study. This is one of the oldest method which is use instead of using concrete they used a steel sheet pile wall, one of the mistake they have done is they used a front main sheet pile wall tied back.

To dead man sheet pile wall they used it in soft clay with lot of silt draining into this area, this soft clay it is recommended not to use this sheet pile walls steel sheet pile walls where soft clay if we go for the earth pressure calculation earth pressure will be very high if it is a medium then sand you can go for steel sheet pile wall they have gone for a soft silt, other problem the design was carried out based on soil investigation not in the final alignment of the berth.

Suppose you want to construct a berth in Icsr building you cannot take the soil investigation at ocean engineering department, originally they propose near ocean engineering department they did the soil investigation based on that soil investigation they have construct it at a berth at Icsr building the soil is different suppose you go to our department of ocean engineering or civil engineering department you get rock at a depth of about 102 meters.

You go to Sharawadhi hostel you get very soft clay, have any of you gone to the academic complex otherwise it was Gandhi to take you there because they are doing the foundation they are doing a isolated footing where they are excavating and they get the rock whereas when you go to Sharawadhi which is very close to the lake where we have very soft clay deposits for a very deep depth may be 3 meter 3 end of meter you won't get the rock.

So for type of foundation required at two different phases are different (academy) at the administrative building in our IIT campus and Sharawadhi hostel the distance may not be more than 100 meters administrative building soil is good,

Sharawadhi hostel it is not good what we see is about 40 to 60 meter spacing you have to do the soil investigation it is likely that within 40 to 60 meter the soil may vary in some places even 20 meters it may vary. So then considering the highly fluid nature of the clay the choice of sheet pile is totally unwarranted,

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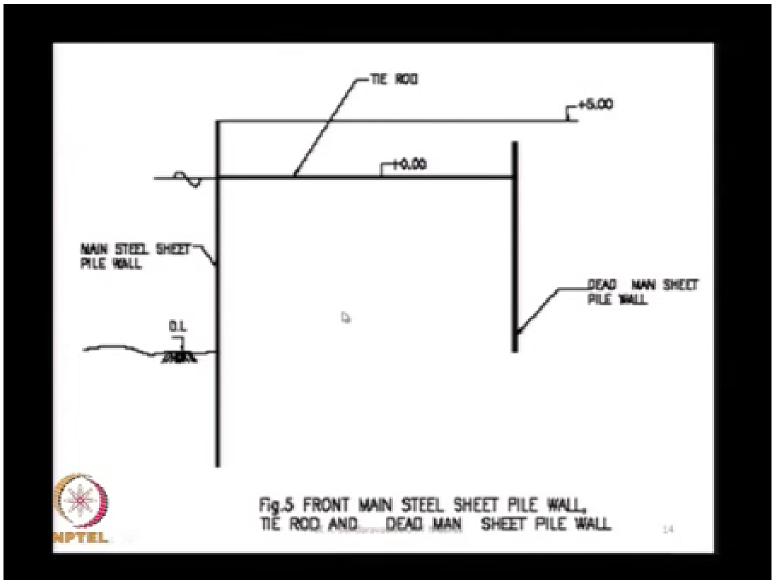

but they have gone for this so they have provided this main wall here they have put the dead man wall here they have located the dead man wall whereas this active zone itself they have located the distance should be more than 30 35 meters they have located within about 20 meters that means the full dead man sheet pile wall will not get any passive resistance.

Only some portions below this active edge only will be resisting. How to failure our structure the soil investigation indicated lesser cohesion compare to the design cohesion assumed based on one borehole investigation this berth is 300 meters, then you go for 300 meters you need at least 6 bore holes what they have done is with one bore hole that also not at the location of the berth, the dead man sheet pile was not located beyond the passive rupture surface.

And was terminated in soft clay is on which was highly undesirable, see when you locate this dead man wall it is not that depth of embedment of the dead man wall it is also where the active piece where the bottom level is, the bottom level should be in either rock or in sand what they have done is in this particular place which is at Vishakhapatnam we have up to this level we have only clay below that you have rock if you have rock what they have to do is they have to bore.

By another equipment then they lower the sheet pile wall, since they didn't do that the both main diaphragm wall as well as the dead man sheet pile wall is not anchored into the rock it is stopping only at the clay so that is not correct.

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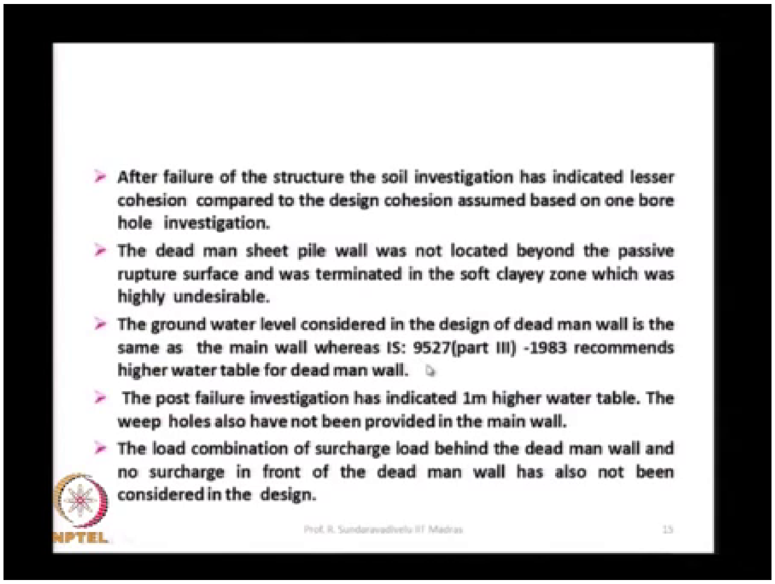

Then the groundwater level considered in the design of dead man wall is the same as the main wall the rest this particular code recommends higher water table for dead man wall so what they say is that's why you have to read the code.

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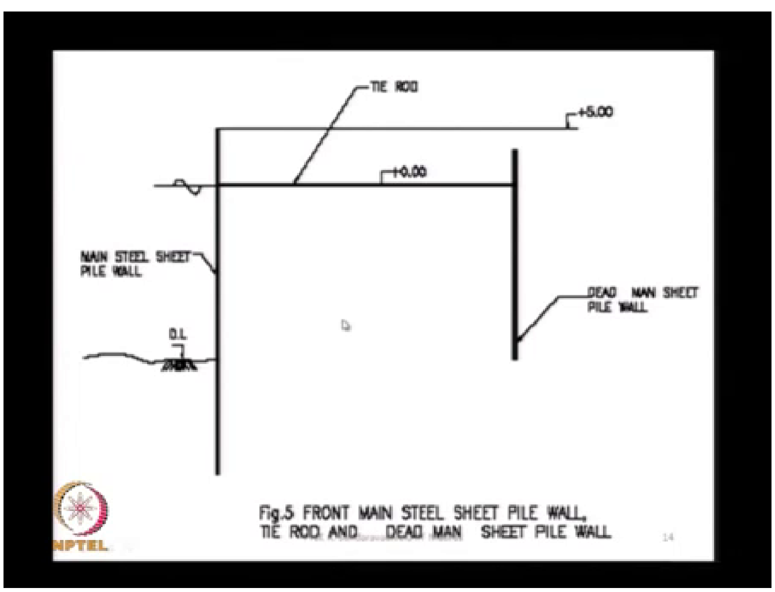

You are assuming some water level here because this is very close to the sea the water level will go up and down not as fast as the tide but it is rapid whereas at this place the water level will not go up and down very fast because this is clay layer which is impermiumable suppose the water level is here the tide level goes down here the water level will not come down very fast is it clear, we will be discussing this on one of the next class how to calculate.

The differential water pressure, differential water pressure means we assume lowest water level here and some ground water level here if it is impermiumable the groundwater level should be very close to the main sea level but at this place it should be as close as to the top level but they have not done this when you do the analysis this is kept at main sea level which is about plus 2 or so this should be kept at plus 5 which they have not done.

The post failure investigation has indicated 1 meter higher water table so they measure the water table after the failure they find water table at this location is 1 meter higher than at this location, the load combination of surcharge load behind the dead man wall and no surcharge in front of dead man wall as also not been considering the design that is when you calculate the earth pressure what you have to do is you have to assume some surcharge load.

What is given in 9527 code is you assume the surcharge here and assume more surcharge here surcharge means we are talking about 50 kilo Newton per meter square that is 5 tons per meter suppose you stack the cargo here about 50 kilo Newton per meter square that means about 5 meter of soil approximately with submerged density of that is another 5 meter soil here that’s what we are assuming to calculate the earth pressure.

What is given in the code is we assume that the cargo is not stacked in this area it is stacked only on the back side that is what to be assumed in the analysis so there are two cases we are considering one is the water level will be assumed higher here another is we assumed the surcharge load only here not here these two cases comes both in the force estimation as well as in the analysis see if we don’t consider these two cases then the structure will fail.

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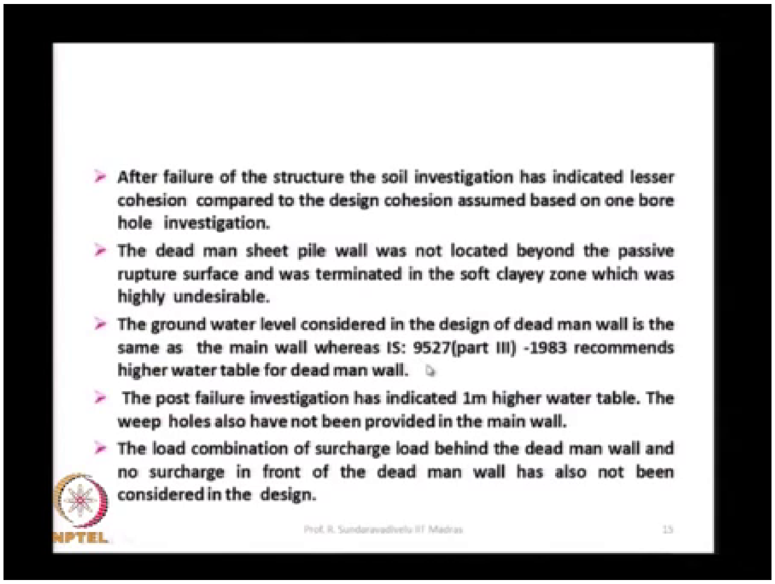

So this is what has happened so I will repeat again the soil investigation adequate number is not done the exact location it is not done dead man sheet pile wall is very close to the main wall it should be further away the founding level should not be in clay third is groundwater level at the dead man wall should be higher than at the main wall the forth is there it is a 1 meter was indicated as the difference the surcharge load should be assumed behind the dead man wall not in front of the dead man wall as one of the load combination.

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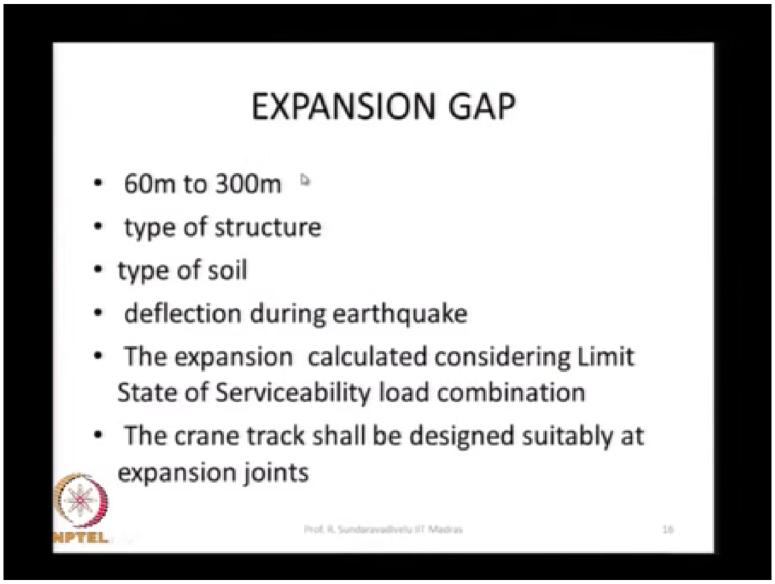

Then about the expansion gap it can vary from 60 meter to 300 meter depends on the type of structure depends on the type of soil, the soil is uniform you can go for 300 meters the soil profile varies it happens in Port Blair every 13 meter also we provide expansion joints, you also should check the deflection during earthquake then expansion calculated considering limit state of serviceability load combination.

We have to calculate and provide that expansion don't provide 20mm 40mm as expansion gap you have to calculate what is the deflection due to temperature difference and accordingly you have to provide the expansion gap especially during earthquake the expansion gap requirement will be more in seismic zone 4, 5 and all, the crane track crane track is continuous that should be designed suitably at expansion joints,

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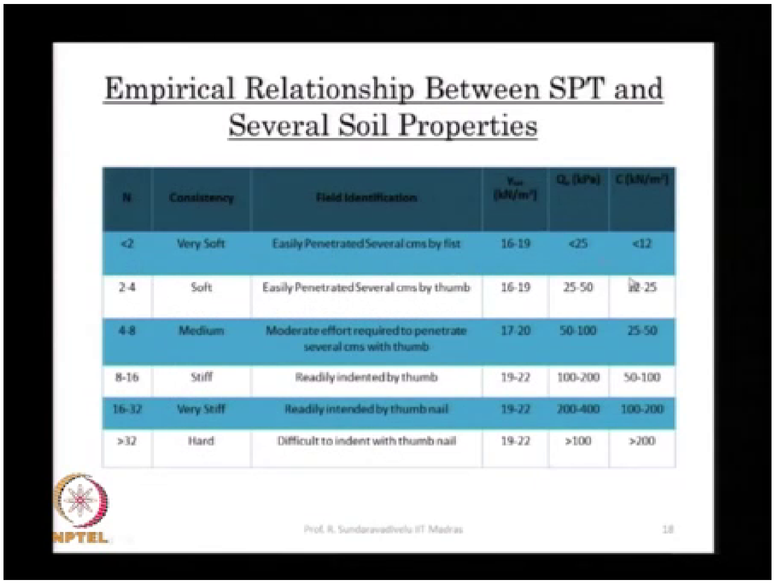

So from next class onwards we will discuss about this soil properties we will continue the discussion.